UNIVERSITY OF SASKATCHEWAN
Department of Physics and Engineering Physics

Physics 115.3
<u>MIDTERM TEST</u>

October 20, 2011   Time: 90 minutes

NAME: _____ **MASTER** _____   STUDENT NO.: _____ _____
          (Last)   **Please Print**   (Given)

LECTURE SECTION (please check):

    ❏   01   B. Zulkoskey
    ❏   02   Dr. R. Pywell
    ❏   03   Dr. K. McWilliams
    ❏   C15 F. Dean

<u>INSTRUCTIONS:</u>

1. This is a closed book exam.

2. The test package includes a test paper (this document), a formula sheet, and an OMR sheet. The test paper consists of 8 pages. **It is the responsibility of the student to check that the test paper is complete**.

3. Only Hewlett-Packard HP 10s or HP 30s or Texas Instruments TI-30X series calculators, or a calculator approved by your instructor, may be used.

4. Enter your name and student number on the cover of the test paper and check the appropriate box for your lecture section. Also enter your student number in the top right-hand corner of each page of the test paper.

5. Enter your name and STUDENT NUMBER on the OMR sheet.

6. The test paper, the formula sheet and the OMR sheet must all be submitted.

7. The marked test paper will be returned. The formula sheet and the OMR sheet will <u>NOT</u> be returned.

ONLY THE <u>THREE</u> PART B QUESTIONS THAT <u>YOU INDICATE</u> WILL BE MARKED

PLEASE <u>INDICATE</u> WHICH <u>THREE</u> PART B QUESTIONS ARE TO BE MARKED

QUESTION NUMBER	TO BE MARKED	MAXIMUM MARKS	MARKS OBTAINED
A1-15	☑	15	
B1	❏	10	
B2	❏	10	
B3	❏	10	
B4	❏	10	
TOTAL		45	

PART A

FOR EACH OF THE FOLLOWING QUESTIONS IN PART A, ENTER THE MOST APPROPRIATE RESPONSE ON THE OMR SHEET.

A1. Using the dimensions given for the symbols in the table, determine which one of the following expressions is dimensionally correct.

(handwritten) C

$$\frac{1}{[T]} \neq \frac{[L]}{[T]^2[L]}$$

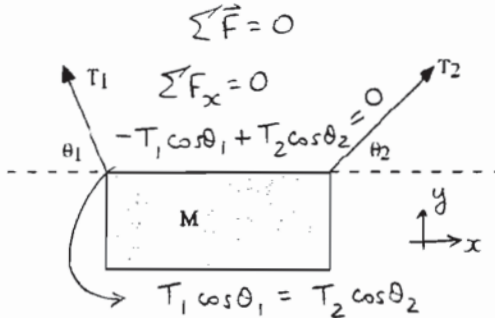| symbol	dimension
f	$\frac{1}{[T]}$
l	$[L]$
g	$\frac{[L]}{[T]^2}$

$$\frac{1}{[T]} \neq \sqrt{\frac{[L]}{[L]/[T]^2}}$$

(A) $f = \dfrac{g}{2\pi l}$ (B) $f = 2\pi g l$ (C) $2\pi f = \sqrt{\dfrac{g}{l}}$ (D) $2\pi f = \sqrt{\dfrac{l}{g}}$ (E) $f = 2\pi\sqrt{gl}$

(handwritten below)
$$\frac{1}{[T]} \neq \frac{[L]}{[T]^2} \cdot [L] \qquad \frac{1}{[T]} = \sqrt{\frac{[L]}{[T]^2} \cdot \frac{1}{[L]}} \qquad \frac{1}{[T]} \neq \sqrt{\frac{[L]}{[T]^2} \cdot [L]}$$

A2. A traffic light of mass M hangs from two cables. Cable 1 has a tension of magnitude T_1, and the cable makes an angle θ_1 with the horizontal, as shown. Cable 2 has a tension of magnitude T_2, and the cable makes an angle θ_2 with the horizontal, as shown. Which one of the following equations is valid for the traffic light?

(handwritten) B

(A) $T_1 + T_2 = Mg$
(B) $T_1 \cos\theta_1 = T_2 \cos\theta_2$
(C) $T_1 \sin\theta_1 = T_2 \cos\theta_2$
(D) $T_1 \cos\theta_1 = T_2 \sin\theta_2$
(E) $T_1 \sin\theta_1 = T_2 \sin\theta_2$

(handwritten diagram annotations)
$\sum \vec{F} = 0$
$\sum F_x = 0$
$-T_1 \cos\theta_1 + T_2 \cos\theta_2 = 0$
$T_1 \cos\theta_1 = T_2 \cos\theta_2$

A3. By what factor does the volume of a cube increase if the lengths of the edges are doubled?

(handwritten) B

(A) 16   (B) 8   (C) 4   (D) 2   (E) $\sqrt{2}$

(handwritten) $V_1 = x_1^3 \qquad V_2 = x_2^3 = (2x_1)^3 = 8x_1^3 = 8V_1$

A4. You have just performed an experiment in which you measured many values of two quantities, A and B. According to theory, $A = cB^3 + A_0$. You want to make a graph of your data that enables you to determine the values of c and A_0 from a slope and a vertical axis intercept. What quantities do you put on the vertical and horizontal axes of the plot?

(handwritten) A

(A) A vertical, B^3 horizontal   (B) A vertical, B horizontal
(C) B vertical, A horizontal   (D) B vertical, A^3 horizontal
(E) A vertical, $\sqrt[3]{B}$ horizontal

(handwritten) $A = cB^3 + A_0$
    $y \quad m \quad x \quad b$

A5. Vector $\vec{A}$ in the drawing is equal to

(handwritten) D

(A) $\vec{C} + \vec{D}$
(B) $\vec{C} + \vec{D} + \vec{E}$
(C) $\vec{C} + \vec{F}$
(D) $\vec{B} + \vec{C}$
(E) $\vec{B} + \vec{F}$
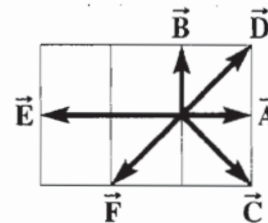
A6. A ball is kicked at an angle of 30° above the horizontal ground. Ignoring air resistance, which one of the following statements correctly describes the situation at the top of the ball's trajectory?

D

(A) The velocity and acceleration of the ball are in opposite directions.
(B) The velocity and acceleration of the ball are both zero.
(C) The velocity and acceleration of the ball are parallel.
(D) The velocity and acceleration of the ball are perpendicular.
(E) The velocity and acceleration of the ball have their maximum magnitudes.
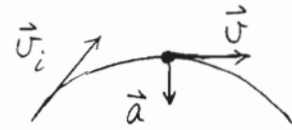
A7. An object is undergoing straight-line motion and the graph of its velocity versus time is shown in the diagram. Which one of the following statements is correct for the situation described by the graph?

C

(A) The velocity of the object is constant. ✗
(B) The velocity of the object is given by the slope of the graph. ✗
(C) The acceleration of the object is constant. ✓
(D) The acceleration of the object is increasing with time. ✗
(E) The acceleration of the object is decreasing with time. ✗
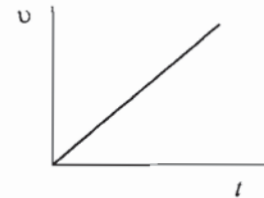
accel'n = slope of
υ vs t.

A8. A pebble (Pebble 1) is thrown horizontally from the top of a tall cliff and lands on the horizontal ground below. At the same time, a second pebble (Pebble 2) is dropped (released from rest) from the top of the cliff. Which one of the following statements is correct?

C

(A) Pebble 1 reaches the ground first, and it has a speed greater than Pebble 2 has when Pebble 2 reaches the ground.
(B) Pebble 2 reaches the ground first, and it has a speed greater than Pebble 1 has when ball Pebble 1 reaches the ground.
(C) Both pebbles hit the ground at the same time, but Pebble 1 has a speed greater than Pebble 2 when they reach the ground.
(D) Pebble 1 reaches the ground first, but both pebbles have the same speed when they reach the ground.
(E) Pebble 2 reaches the ground first, but both pebbles have the same speed when they reach the ground.

Vertical motions are the same, and time depends on vertical motion

A9. An object moves along the x-axis. The graph shows the velocity of the object as a function of time. In which time interval(s) (labeled a, b, c and d on the graph) is the acceleration of the object zero?

D

(A) Time intervals a, b, c and d.
(B) Time intervals b, c and d.
(C) Time intervals b and c.
(D) Time intervals a and d.
(E) Time interval a only.
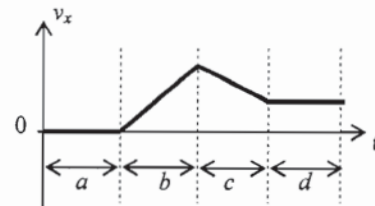
accel'n is zero when velocity is constant

A10. If a net force, with magnitude F, acts on a blue object with mass m, the object has an acceleration with magnitude a. If a net force with a magnitude which is 6 times F acts on a red object with mass 3 times m, the red object has an acceleration with magnitude…

B

(A) $3a$ (B) $2a$ (C) $a/2$ (D) $a/6$
(E) that cannot be determined, since the answer depends on the direction of the net force acting on the red object.

$$BLUE: \quad F = ma_{blue}$$
$$a_{blue} = \frac{F}{m} = a$$

$$RED:$$
$$6F = 3m \cdot a_{red}$$
$$a_{red} = \frac{6F}{3m} = 2\left(\frac{F}{m}\right)$$
$$a_{red} = 2a_{blue} = 2a$$

A11.   A car travels around a circular curve without slipping. When the road surface is horizontal, which force is responsible for holding the car on the road in the circular path as it travels around the curve?

C

(A)   the weight of the car
(B)   the kinetic friction force between the tires of the car and the road
(C)   the static friction force between the tires of the car and the road
(D)   the vertical component of the normal force
(E)   the horizontal component of the normal force
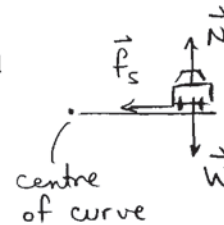
A12.   A big truck and a small car drive around the same circular curve in a road. The mass of the truck is four times larger than the mass of the car. If they drive around the curve at the same speed then what is the ratio of the radial acceleration of the truck, a_{rt}, compared to that of the car, a_{rc}. In other words, what is a_{rt}/a_{rc}?

C

(A) 4   (B) 2   (C) 1   (D) ½   (E) ¼

$$a_r = v^2/r \quad so \quad a_{rt} = a_{rc}.$$

A13.   Consider an object moving in a circular path with constant speed. Which one of the following statements is **TRUE**?

B

(A)   The speed is constant so the magnitude of the acceleration is zero. F (a_r)
(B)   The speed is constant so the component of the acceleration in the direction of motion is always zero. T
(C)   The distance from the center is constant so the radial component of the velocity is always zero so the radial component of the acceleration must be zero. F (a_r)
(D)   The component of the acceleration in the direction of motion is not zero. F
(E)   The radial component of the acceleration and the component of acceleration in the direction of motion have equal magnitudes. F

A14.   A satellite of mass m moves with a speed v in a stable circular orbit around the Earth. If a second satellite of mass $2m$ is placed in the same stable circular orbit, what must be its speed in order to maintain this orbit?

C

(A) ¼ v (B) ½ v (C) v (D) 2 v (E) 4 v

$$\Sigma F_r = ma_r \Rightarrow \frac{GMm}{r^2} = m\frac{v^2}{r} \Rightarrow v = \sqrt{\frac{GM}{r}}, \text{ no dependence on } m.$$

A15.   An object is moving with an angular speed ω_1 in a uniform circular path of radius r_1. If the angular speed is doubled and the radius remains the same then which one of the following expressions for the new radial acceleration is correct?

B

(A) $2r_1\omega_1^2$ (B) $4r_1\omega_1^2$ (C) $8r_1\omega_1^2$ (D) $r_1\omega_1^2$ (E) $6r_1\omega_1^2$

$$a_{r_1} = r_1\omega_1^2 \quad , \quad a_{r_2} = r_2\omega_2^2 = r_1(2\omega_1)^2 = r_1(4\omega_1^2) = 4r_1\omega_1^2$$

PART B

ANSWER <u>THREE</u> OF THE PART B QUESTIONS ON THE FOLLOWING PAGES AND <u>INDICATE YOUR CHOICES ON THE COVER PAGE</u>.

FOR EACH OF YOUR CHOSEN PART B QUESTIONS ON THE FOLLOWING PAGES, GIVE THE COMPLETE SOLUTION AND ENTER THE FINAL ANSWER IN THE BOX PROVIDED.

THE ANSWERS MUST CONTAIN THREE SIGNIFICANT FIGURES AND THE UNITS MUST BE GIVEN.

<u>SHOW AND EXPLAIN YOUR WORK</u> – NO CREDIT WILL BE GIVEN FOR ANSWERS ONLY.

EQUATIONS NOT PROVIDED ON THE FORMULAE SHEET MUST BE DERIVED.

USE THE BACK OF THE PREVIOUS PAGE FOR YOUR ROUGH WORK.

B1. You wish to hang a picture frame on the wall, but first you must decide where to put it. A
     friend holds the picture frame stationary against the wall while you observe. The picture frame
     has a mass of m. The coefficient of static friction between the frame and the wall is μ_s. Your
     friend pushes on the picture frame with a force of magnitude F_{push} at an angle of θ with the
     vertical, as shown in the diagram. The friend pushes with the minimum force needed to prevent
     the picture from sliding down the wall.
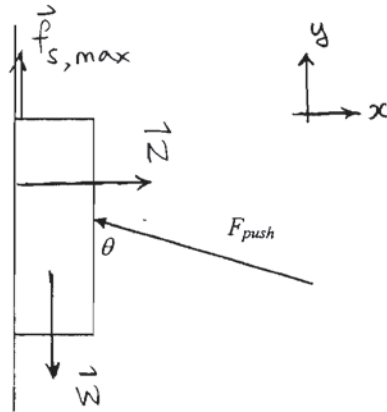
$$W = mg$$

$$f_{s,max} = \mu_s N$$

(a) Draw the free body diagram of the picture frame. (*4 marks*)

(b) Derive an expression for the magnitude of the minimum force with which your friend must
    push to prevent the picture frame from sliding down the wall. (*6 marks*)

minimum pushing force
corresponds to f_s being $f_{s,max}$

The picture is not moving,

so $\sum \vec{F} = 0$.

$$\boxed{F_{push_{min}} = \frac{mg}{\mu_s \sin\theta + \cos\theta}}$$

$\sum F_x = 0$ and $\sum F_y = 0$

$N_x + F_{push_{min}x} = 0$ $f_{sy} + W_y + F_{push_{min}y} = 0$

$+N - F_{push_{min}} \sin\theta = 0$ $+f_{s,max} - W + F_{push_{min}} \cos\theta = 0$

$N = F_{push_{min}} \sin\theta$ $\mu_s N - mg + F_{push_{min}} \cos\theta = 0$

$\mu_s \left(F_{push_{min}} \sin\theta \right) - mg + F_{push_{min}} \cos\theta = 0$

$F_{push_{min}} \left[\mu_s \sin\theta + \cos\theta \right] = mg$

$$\boxed{F_{push_{min}} = \frac{mg}{\mu_s \sin\theta + \cos\theta}}$$

B2. A knight is attempting to throw a rock from the top of a
castle wall to hit a person on the horizontal ground
below. The rock is thrown with an initial speed of
$v_i = 4.60$ m/s in a direction that makes an angle $\theta = 52.0°$
with the vertical castle wall. The person is a distance of
$d = 7.00$ m from the base of the castle wall. The rock
falls short of its target and hits the ground at a time of
1.51 s after it was thrown. (We may ignore air resistance
in this problem.)
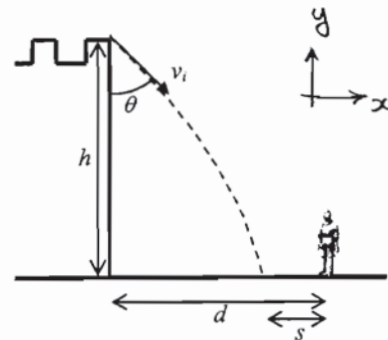
(a) Calculate the distance, s, by which the rock falls short
of its target. (*4 marks*)

x	y
$\Delta x = d - s$	$\Delta y = -h$
$v_{ix} = v_i \sin\theta$	$v_{iy} = -v_i \cos\theta$
$a_x = 0$	$a_y = -g$
$v_{fx} = v_{ix}$	$v_{fy} = ?$

$\Delta t = 1.51 s$

$$\boxed{1.53 \text{ m}}$$

$$\Delta x = v_{ix} \Delta t + \frac{1}{2} a_x (\Delta t)^2$$
$$\overset{"0}{}$$

$$\Delta x = v_{ix} \Delta t$$

$$d - s = v_{ix} \Delta t$$

$$s = d - v_{ix} \Delta t$$

$$s = d - v_i \sin\theta \Delta t$$

$$s = 7.00 m - (4.60 m/s)(\sin(52.0°))(1.51 s)$$

$$\boxed{s = 1.53 m}$$

(b) Calculate the height, h, of the castle wall. (*6 marks*)

$$\Delta y = v_{iy} \Delta t + \frac{1}{2} a_y (\Delta t)^2$$

$$\boxed{15.4 m}$$
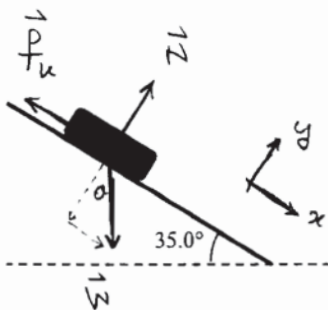
$$-h = -v_i \cos\theta \Delta t + \frac{1}{2}(-g)(\Delta t)^2$$

$$h = v_i \cos\theta \Delta t + \frac{1}{2} g (\Delta t)^2$$

$$h = (4.60 m/s)(\cos 52.0°)(1.51 s) + \frac{1}{2}(9.80 m/s^2)(1.51 s)^2$$

$$\boxed{h = 15.4 m}$$

B3. A book is placed on a wooden plank which is at an angle of 35.0° to the horizontal. After the book
     is released it is measured to slide down the plank with an acceleration of 2.18 m/s².

(a) Draw the free body diagram of the book. (*3 marks*)

(b) Calculate the coefficient of kinetic friction between the book and the plank. (*4 marks*)

Choose the x-axis along the plank
as shown. Then $\Sigma F_x = ma$ and $\Sigma F_y = 0$

$$\boxed{0.429}$$

$\Sigma F_x = ma$

$W_x + f_{kx} = ma$

$+W\sin\theta - f_k = ma$

$mg\sin\theta - \mu_k N = ma$

$\cancel{m}g\sin\theta - \mu_k \cancel{m}g\cos\theta = \cancel{m}a$

$g\sin\theta - a = \mu_k g\cos\theta$

$\Sigma F_y = 0$

$N_y + W_y = 0$

$+N - W\cos\theta = 0$

$N = mg\cos\theta$

$$\mu_k = \frac{g\sin\theta - a}{g\cos\theta} = \frac{(9.80\ m/s^2)(\sin 35.0°) - 2.18\ m/s^2}{(9.80\ m/s^2)(\cos 35.0°)} = \boxed{0.429}$$

(c) If the book was released from rest, calculate the speed of the book after it has moved down the
     plank a distance of 66.0 cm. (*3 marks*)

$$U_{fx}^2 - U_{ix}^2 = 2a_x \Delta x$$

$$\boxed{1.70\ m/s}$$

$$U_{fx}^2 = \underset{\substack{\| \\ 0}}{U_{ix}^2} + 2a_x \Delta x$$

$$U_{fx} = \sqrt{2a_x \Delta x}$$

$$U_{fx} = \sqrt{2(2.18\ m/s^2)(0.660\ m)}$$

$$\boxed{U_{fx} = 1.70\ m/s}$$

B4. A vertical rod is rotating at a constant rate. A ball of mass 3.00 kg is attached to the top and
bottom of the rod by strings of equal length, as shown in the diagram. The strings make an angle
of $\theta = 33.6°$ with the vertical. Due to the rotation of the rod, the ball moves in a horizontal circle
of radius 1.66 m at a constant speed of 10.0 m/s.

(a)   Draw the free body diagram of the ball. (*2 marks*)
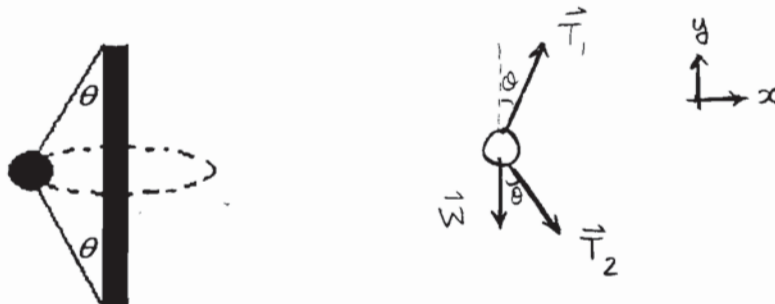
(b)   Calculate the magnitude of the radial acceleration of the ball. (*3 marks*)

$$a_r = \frac{v^2}{r}$$

$$\boxed{60.2 \ m/s^2}$$

$$a_r = \frac{(10.0 \, m/s)^2}{1.66 \, m} = \boxed{60.2 \, m/s^2}$$

(c)   Calculate the magnitude of the tension in the lower string. (If you did not obtain an answer
for (b), use a value of 65.0 m/s².) (*5 marks*)

motion is horizontal, so $\sum F_y = 0$

$$\boxed{146 \, N}$$

$$T_{1y} + W_y + T_{2y} = 0$$

$$+ T_1 \cos\theta - W - T_2 \cos\theta = 0$$

$$\boxed{T_1 = \frac{W}{\cos\theta} + T_2}$$

x is the radial dir'n,

so $\sum F_x = ma_r$

$$T_{1x} + T_{2x} = ma_r$$

$$T_1 \sin\theta + T_2 \sin\theta = ma_r$$

$$\left(\frac{W}{\cos\theta} + T_2\right) \sin\theta + T_2 \sin\theta = ma_r$$

$$W \tan\theta + T_2 \sin\theta + T_2 \sin\theta = ma_r$$

$$2T_2 \sin\theta = ma_r - W\tan\theta$$

$$T_2 = \frac{ma_r - mg\tan\theta}{2\sin\theta} = \frac{3.00 \, kg\left[(60.2 \, m/s^2) - (9.80 \, m/s^2)(\tan 33.6°)\right]}{2 \sin 33.6°}$$

END OF EXAMINATION

$$\boxed{T_2 = 146 \, N}$$

(ALT ANS: $159 N$)